Baseline Research on Marine Debris, Including Plastic Pollution, in Xuan Thuy National Park - Nam Dinh, Vietnam

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Addressing Marine Plastics
A Systemic Approach

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Background

The Red River Delta is a biodiversity hotspot in the western coastal zone of the Tonkin Gulf, supporting mangrove forests, intertidal habitats, and a key feeding ground for a number of bird species that stop on route during spring and autumn migrations. Out of the seven coastal wetlands in the Red River Delta, Xuan Thuy National Park, located on the right bank side of the estuary in Nam Dinh province of Vietnam, is considered one of the most important ecological sites. According to the park's official website, Xuan Thuy National Park was recognized for the fundamental ecological functions performed by its wetlands when it was declared the first Convention on Wetlands (Ramsar) Site in Vietnam in 1982. Xuan Thuy National Park alone has over 14 different mangrove species in its forests, providing an abundant source of food and shelter for over 30 marine species and an important habitat for migratory birds, with 78 species of water birds and 38 species of shorebirds recorded. In addition to being a habitat for rare species of otter, porpoise, and whale, the area has also recorded 111 aquatic plant species, and over 500 species of benthic invertebrates and zooplankton, including shrimp, fish, crab, and oysters. Not only does the Xuan Thuy site serve as a rich habitat for many threatened species, it also provides natural resources and economic prospects for the livelihood of local human communities.

Due to its importance as a site of socioeconomic development in Vietnam, as well as an increasing human population and therefore growing use of its highly valuable resources, there have been many reports and studies done on various issues within the Red River estuary to address these challenges. These studies were funded and supported by a range of academic institutions and international organizations, including the Hai Phong Institute of Oceanography, the Institute for Ecology and Biological Resources, Hanoi (IEBR), the World Conservation Union (IUCN), the Mangrove Ecosystem Research Centre (MERC), and the Ministry of Agriculture and Rural Development (MARD) among others. According to Thanh (2003), there were major gaps in the research that made it difficult to track ongoing changes to the ecosystem and the causes behind those changes. In the following years leading to the present, more studies have been done to assess the impact of anthropogenic change particularly on the Xuan Thuy Ramsar site. Thanh and Yabar (2015) described the vulnerability of Vietnam's coastal wetlands and presented an overview of the main challenges for the sustainable management of the Xuan Thuy Ramsar site. Their research, in addition to that of others, shows that there needs to be the development of a long-term conservation plan. Other research related to Xuan Thuy site look into more specific areas, such as one that analyzes environmental stressors on Xuan Thuy's mangroves (Haneji et al., 2014) and another that discusses the importance of local community knowledge and reactions to natural hazards (Lam, 2016). Previous literature thus far suggests multiple areas of research opportunities that would greatly contribute to the ongoing conversation about the Red River estuary and its conservation, and would further inform national and local stakeholders about the best strategies to improve sustainable measures for this area.

In particular, research about marine debris (including plastic pollution) is in its infancy in Vietnam. In total, to the best of our knowledge, we could only find one paper in the literature discussing research on marine debris. A study by Lahens et al. (2018) described macro- and micro-plastic contamination in the Saigon River. Due to work by Jambeck et al. (2015), showing Vietnam as a priority country for research and mitigation strategies relevant to marine debris, conservation groups and local governments have become concerned about the impacts of marine debris on the ecosystems and resources in Vietnam. In response to growing concerns about the sources, quantities and effects of marine debris in Vietnam, we formed a collaboration between Ocean Conservancy (OC), Centre for Marinelife Conservation and Community Development (MCD), and the Vietnam Administration of Seas and Islands (VASI) to begin baseline work to start to understand sources, fate and effects of marine debris, including microplastics (plastic debris <5mm in size), in this region. Due to its importance as a biodiversity hotspot, a national conservation area, and resources for local populations, we chose to focus our work on Xuan Thuy National Park in the Red River Delta.

With MCD, we agreed upon three main research objectives and designed research protocols to meet them. These objectives included:

1. Conducting a baseline study of plastic pollution in the Red River Delta:
    a. Quantify and characterize anthropogenic debris (e.g., plastic, metal, glass) along the shorelines and tidal flats of the estuary and mangrove forest, and upstream of the delta in and along the Red River.
    b. Quantify and characterize microplastics along the shorelines and tidal flats of the estuary.
2. Compare the types and distribution of anthropogenic debris from the river to the ocean across the region to inform sources and fate.
    a. Assess patterns for quantification and characterization of anthropogenic debris across the region to inform sources
3. Assess how anthropogenic debris affects mangroves and the biodiversity within the mangrove ecosystem, ultimately affecting local people and the planet.

In addition to the research objectives listed above, our objectives also included capacity building to transfer and share information about the science of marine debris and methods for researching the sources, fate and effects of marine debris – all to inform a national strategy for marine debris in Vietnam. In addition to capacity building with MCD and VASI, our week in Vietnam included a focus group led by MCD to share with the local community of Xuan Thuy National Park what we were doing and to determine the knowledge and perceptions about marine debris amongst local people. This focus group was an initial meeting to discuss the issues and a follow-up meeting to share results will follow.

(Left: Chelsea, Cindy, and Rachel from OC; Right: MCD, VASI, and Xuan Thuy National Park rangers)

To carry out the research and meet our objectives, three researchers representing OC went to Vietnam to work with MCD and VASI from May 27th through June 1st. The group included Dr. Chelsea Rochman (Professor at University of Toronto), Ms. Rachel Giles (MSc student at University of Toronto) and Ms. Cindy Nguyen (Ray Fellow at OC). Upon arrival, we met with MCD, VASI and the rangers at Xuan Thuy National Park to discuss our work together. During this meeting we made introductions, discussed the reasons behind our collaboration, determined the feasibility of the protocol and determined a plan of action for the week. Initial meetings including a drive and boat ride around the park to look at sites for the research. The final site visit included an initial sampling to test out the protocol and share our methods with others that would not be doing research with us daily throughout our time in the park.

The following days – Wednesday through Friday – were consumed by sampling sites and performing the research. On Saturday, we had a meeting at MCD to share initial results and discuss next steps. The following is an overview of the methods and results from the research, a discussion about our results and their significance and next steps.

(Left: First day on the boat to look at sites; Right: Chelsea and Rachel standing at Site 4)

Methods

To meet all of our objectives (1, 2 and 3), locations were selected within the park to characterize marine debris, microplastics and assess measures of biodiversity and ecosystem health. For this, we selected sites within and nearby Xuan Thuy National Park along the river (Site 5), at the river mouth (Site 1), within the protected delta (and near intensive aquaculture; Site 3) and facing the ocean (Sites 2 and 4; see map in Figure 1). The variability and spatial separation of these sites were selected to help meet the goals of Objective 2 – assessing sources and fate.

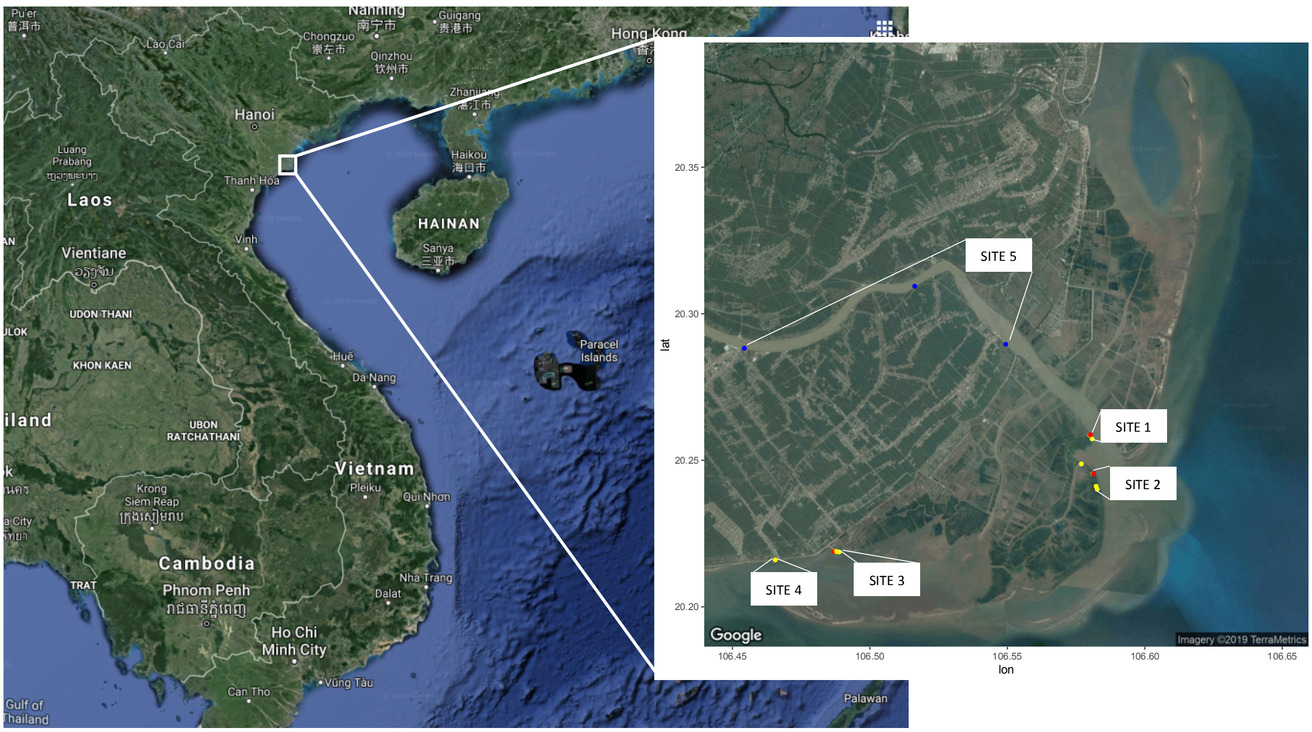

Figure 1. Site overview. Yellow dots demarcate where transects were surveyed for (1) anthropogenic debris, (2) microplastics, and (3) biodiversity along the shoreline within the mangroves. Red dots demarcate where transects were surveyed for (1) anthropogenic debris, (2) microplastics, and (3) biodiversity, along the tidal flats. Blue lines demarcates where transects were surveyed for (1) anthropogenic debris, and (2) microplastics.

Objectives 1 and 2: Quantify and characterize marine debris, including microplastics, at various sites within the Red River Delta, and specifically Xuan Thuy National Park. Compare marine debris composition among sites to help determine sources and fate.

At each site, we aimed to conduct three to five surveys within 50m x 5m transects. There were a few exceptions due to high litter accumulation or difficult site access whereby we sampled from less locations within a site or from smaller transects. When smaller transects were conducted, the size of the transect was always noted clearly in the datasheets. Within each transect, all debris was characterized by number of items per m^2 and thus consistency in size amongst the transects was less important. At sites 1, 2 and 3, three transects were taken from each site at the high tide line in the mangrove forest (yellow transects in Figures 1). For one yellow transect location at each of sites 1, 2 and 3, two transects (red in Figure X) were conducted moving from high tide towards the edge of the water spacing each transect about 5m apart. At site 4, only one transect was conducted at the high tide line. This was an extra site used for initial training and demonstration with stakeholders. At site 5, three transects were conducted only (blue transects in Figure X) along the Red River moving outside the park towards inland.

Upon arrival at each location, a transect was laid out using transect tape and marked with bright orange flags. GPS coordinates were recorded from each corner of the transect and pictures of the transect were taken. Within each transect, we characterized anthropogenic debris >2.5 cm in size. For this research, we conducted standing stock surveys, which means we did not collect and clean-up the litter at each site. To quantify and characterize the debris in each transect, each transect was split into three sections and each section was assessed by one or two individuals. In general, we worked in three pairs with one person from OC working with one person from MCD or VISI. Each pair of researchers surveyed one section of the transect on their own data sheet (0-15m, 15-30m, 30-50m) to later be compiled together. Walking each transect in a pattern that was perpendicular to the high tide line, and in a zig-zag formation, all litter items were recorded on data sheets for all debris items more than 2.5 cm in the longest dimension. The material types were recorded in accordance with the datasheet associated with the NOAA Marine Debris Shoreline Survey Field Guide (Opfer et al., 2012). Photos were taken of all transects.

(Left: Transect at Site 1; Right: Site 3)

To characterize microplastics**,** surface sediments were collected in the center of each surveyed transect within a 10 x 10cm transect. Surface sediment samples were taken with a clean metal spoon and scooped into a clean polypropylene specimen jar. A picture was taken of each small quadrat sampled for microplastics. At the field station in the park, samples were sieved using a 2mm sieve and identified visually as microplastics. All microplastics found were characterized by color and shape. Because sample processing and analysis were done in the field, particles <2mm in size were not included to be conservative since no microscopes or instrumentation for chemical analysis were available. A field blank was taken each day, and no microplastics were identified in any field blank sample.

(Ngoc Ngo from MCD collecting microplastic sample)

To characterize debris and compare amongst sites, we quantified the total amount of debris per m^2 and assessed how the totals compared amongst sites. We also noted the dominant debris type overall. To assess sources and fate of marine debris in the region, we assessed the relationships and/or differences among sites upstream, in the park and closer to the ocean. Within each site the types of debris were assessed and analyses were conducted to look at whether there were similarities among sites.

Objective 3: Assessing the ecological effects of marine debris in Xuan Thuy National Park.

To assess whether marine debris affects the ecosystem within the Red River Delta we used several measurements as bio-indicators of the impact of humans on ecosystems health. First, we measured the number of crab holes within each transect (as in Gul and Griffen et al., 2018). We also assessed the health of the mangroves as an indicator of ecosystem health (as in the *Environmental Protection (Water) Policy 2009 – Monitoring and Sampling Manual)*. We measured the width of the mangrove trunk and canopy cover under each tree. More details for each measurement are as follows.

First, to measure crab holes as an indicator of human impact on the ecosystem, we dropped three 1m x 1m quadrats randomly in the transect: one between 0-15m, one between 15-30m and one between 30-50m. For each quadrat, GPS coordinates at the center of the quadrat were recorded and a picture was taken. We measured the number of crab holes that were equal to or larger than our smallest finger within each quadrat. As a measure of impact, we measured the relationship between the amount of marine debris per m^2 in the transect and the average number of crab holes across the three quadrats within a transect using a simple linear regression in R.

(Cong Nguyen from MCD during crab hole assessment)

Second, as an indicator of ecosystem health, the mangroves along the high tide line were assessed within each transect. Walking along the long edge of the top of the transect, we measured the diameter of one tree just before the first branch and canopy cover on a randomly selected tree every 5 m (i.e., 0m, 5m, 10m, 15m, 20m, 30m, 35m, 40m, 45m, and 50m). Thus, in total we assessed 10 trees per transect. Mangroves were selected based on height, attempting to standardize mangrove height within a transect. The largest mangrove trees within the transect were assessed for these measurements, ignoring young trees. The diameter of each tree was measured using a measuring tape and recorded to the nearest centimeter. For canopy cover, we used the app Light Meter Pro on our smart phones and recorded the light intensity (lux) outside of each mangrove and directly under the mangrove canopy. As a measure of canopy cover, the light measurement taken from under the mangrove tree was subtracted from the light measurement taken from the open air. As an assessment of whether marine debris affected ecosystem health, we measured the relationship between both the amount of marine debris per m^2 in the transect and the average width of the mangrove trees across the transect and the amount of marine debris per m^2 in the transect and the average canopy cover of the mangrove trees across the transect using simple linear regressions in R.

Results

Objectives 1 and 2: Quantify and characterize marine debris, including microplastics, at various sites within the Red River Delta, and specifically Xuan Thuy National Park. Compare marine debris composition among sites to help determine sources and fate.

We characterized the amount and types of marine debris at all locations within each of the five sites within our study. Plastic was the most common type of debris found, making up 86.6% of all debris quantified (Figure 2). Moreover, we found that the concentrations of marine debris (# of items per m^2) varied amongst sites with the largest concentrations at sites 2C, 4, 5A, 5B and 5C (ranging from 6.1 to 16.9 items per m^2). The sites with the fewest number of items were sites 1CR1, 1CR2, 2CR2, 3AR1 and 3AR2 (ranging from 0.1 to 0.3 items per m^2) – all sites below the high tide line. In addition sites 1A and 3A had relatively fewer debris items (0.4 and 0.5 items per m^2 respectively). For concentrations among all sites, see Figure 3 below.

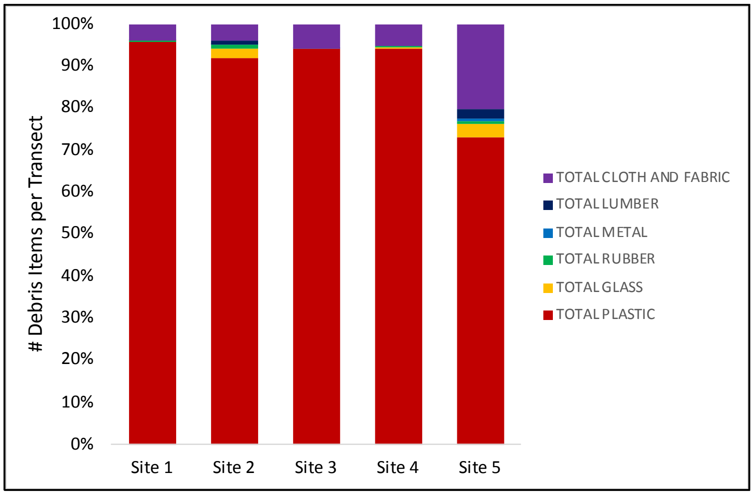

Figure 2. Bar graph showing the percentage of each type of debris (textiles, lumber, metal, rubber, glass and plastic) found at locations within each of the five sites. Each bar is dominated by blue, indicating that plastic debris was the most common type of debris found across all sites.

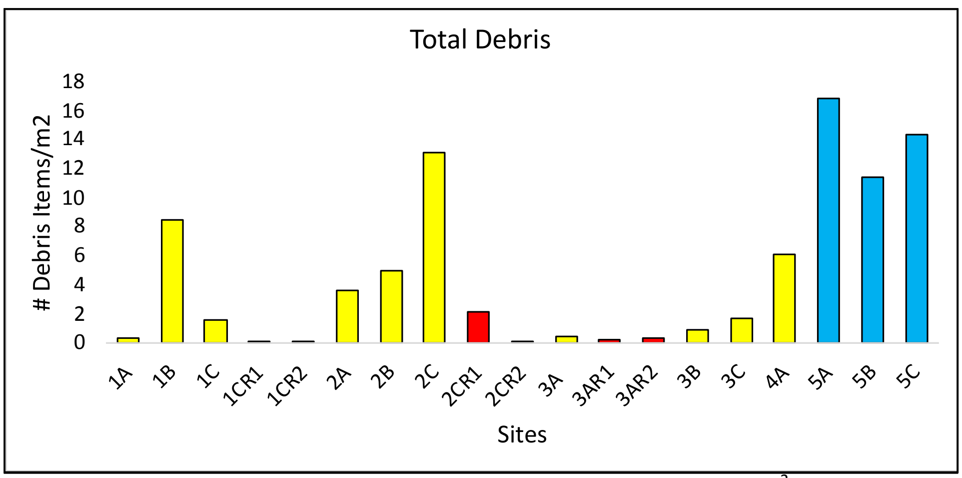

Figure 3. Bar graph showing the total amount of items of anthropogenic debris per m^2 at each location within all five sites. Locations assessed at the high tide line in the national park are in yellow, locations assessed closer to the water are in red, and locations upstream in the Red River are in blue.

For microplastics, patterns amongst sites were consistent with larger debris items. Microplastics were only found at eight sites: 1B, 2B, 2C, 2CR1, 4, 5A, 5B and 5C (Figure 4). Each of these sites were also sites with relatively large quantities of marine debris >2.5 cm in size.

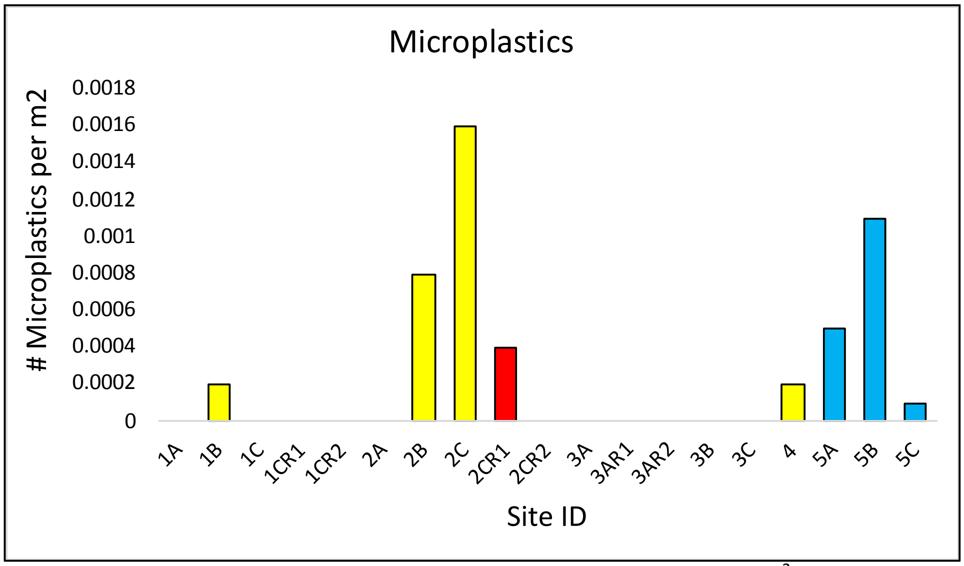

Figure 4. Bar graph showing the total amount of items of anthropogenic debris per m^2 at each location within all five sites. Locations assessed at the high tide line in the national park are in yellow, locations assessed closer to the water are in red, and locations upstream in the Red River are in blue.

To help assess sources and fate of marine debris in the region, we assessed the similarity or differences among patterns of debris between sites. We expected the characterization of debris to differ between sites closer to the river from sites closer to the ocean. We also expected to see items associated with fishing and aquaculture at sites 2 and 4 based on their proximity to relatively greater fishing and aquaculture related activities.

First, we simply looked at the top items of debris at leach site. Figure 5 shows the top ten debris items at each site (i.e., the total debris from each location within each site). From the figure, it is clear that there are differences among sites, suggesting different sources of marine debris to the Red River and the estuary. Sites 1, 4 and 5 have many food wrappers and plastic bags. These sites are situated in the river, at the river mouth or closer to the open ocean. This suggests that the river is a source of debris to site 4, which was closer to the ocean. Sites 2 and 3 have more items associated with fisheries – namely fragments of foams from coolers, ropes and nets, and fishing line. Sites 2 and 3 were in Xuan Thuy National Park and close to fishing and aquaculture. This suggests that the fishing and aquaculture industries are also a source of marine debris to the Red River Delta. Overall, plastic bags and food wrappers were common amongst all sites. Fabric pieces were also common amongst all sites. In general, the top ten items were plastic debris, with the exception of glass bottles and fragments at sites 4 and 5. Fabric pieces may be made from synthetic textiles, but some may be made from natural fibers (e.g., cotton) and thus not be plastic debris.

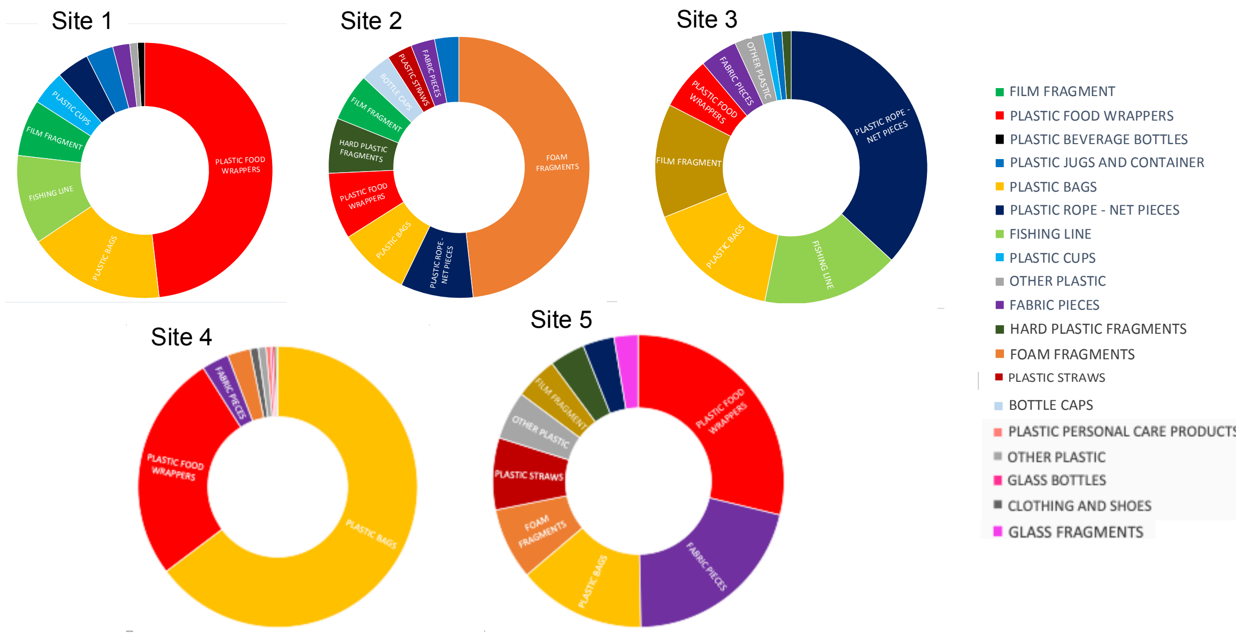

Figure 5. The proportion of the top 10 debris items found within all locations within each of the five sites. The types of debris are characterized by color and the legend showing which color matches which debris type is on the right side.

To look closer at similarities amongst sites regarding all marine debris collected, we visually analyzed our data using nMDS (Figure 6). An nMDS plot was created with all data across all sites using the Bray-Curtis dissimilarity metric and plotted in two dimensions. The data was not transformed and the stress value was 0.07. Each point on the figure represents a sampling location, and the different shapes represent each of the five sites. When points are closer to each other, this can be interpreted as sites being similar in terms of the amounts and types of debris found. Here, for sites 1 and 5 (the two sites in the river and river mouth), replicates within each site group together and the two sites are located next to each other in space. Site 4, an ocean site slightly outside the estuary and on a beach, groups closest to the two river sites (1 and 5) – similar to what we see above in Figure 5. For sites 2 and 3, the points are together with each other, but also divided by the points from site 1 in the mouth of the river. This may also suggest influence from the river sites in addition to external influence from fisheries and aquaculture, as noted above.

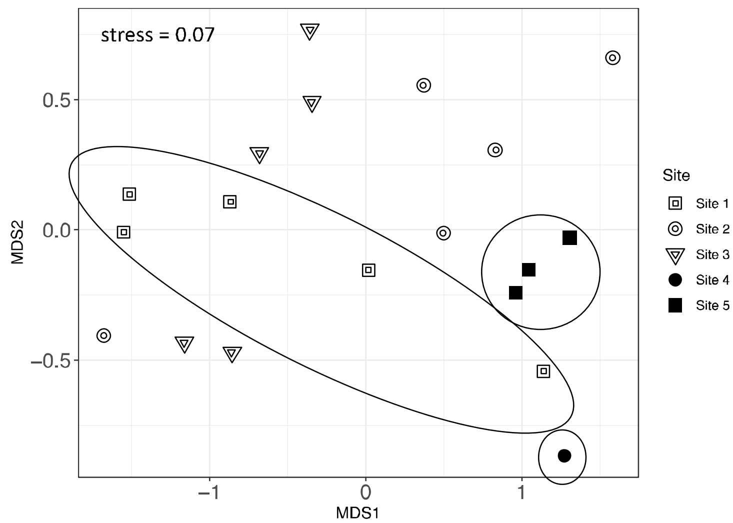

Figure 6. An nMDS plot created using data collected regarding all debris items across all locations within each of the five sites using the Bray-Curtis dissimilarity metric and plotted in two dimensions. Data was not transformed. Each point on the figure represents a sampling location, and the different shapes represent each of the five sites.

Objective 3: Assessing the ecological effects of marine debris in Xuan Thuy National Park.

For objective 3, we asked whether marine debris in and around Xuan Thuy National Park had an ecological effect. To answer this question, we used different measurements as indicators of biodiversity and ecosystem health. As in Gul and Griffen et al., (2018), we quantified the number of crab holes within each transect as an indicator of biodiversity. To do this, we took the average number of crab holes within three random 1m x 1m quadrats distributed across each transect. Although we observe a slight trend showing less crab holes with increasing amounts of marine debris, the relationship is not significant (p=0.17; Figure 7). This suggests that marine debris may not reduce the biodiversity within the park. Still, further research should be conducted to explore this trend further since there is a non-significant trend suggesting that marine litter may negatively affect biodiversity using this metric.

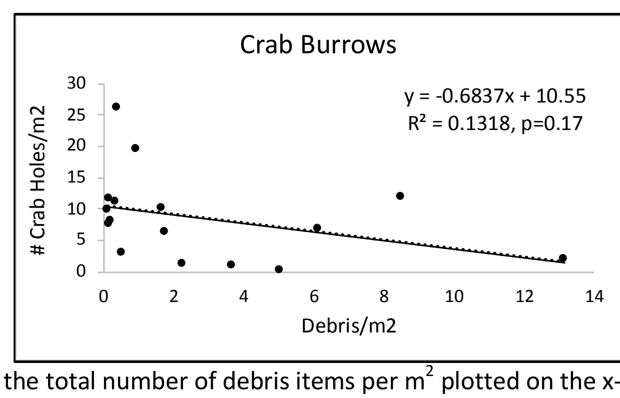

Figure 7. A scatter plot with the total number of debris items per m^2 plotted on the x-axis and the number of crab holes per m^2 plotted on the y-axis. A trendline for a linear regression is shown with the equation, R^2 value and p value denoting significance.

As in the *Environmental Protection (Water) Policy 2009 – Monitoring and Sampling Manual*, we measured the diameter and canopy cover of mangroves within a transect as an indicator of ecosystem health. To do this, we took the average size of the mangrove trunk just before branching and the average canopy cover (measured in lux) of 10 mangroves within each transect. Although there was a slight trend showing a smaller diameter of a mangrove with increasing amounts of marine debris, the relationship was not significant ($p=0.51$; Figure 8 left). For canopy cover, there was a significant relationship ($p<0.05$; Figure 8 right) whereby more marine debris was correlated with increased light under the mangrove. This translates to more marine debris correlating with reduced canopy cover. This suggests that marine debris may reduce the ecosystem health within the park when canopy cover is used as an indicator. For mangrove diameter, we did not see a significant relationship, but similar to the measurements of crab holes further research should be conducted to explore this trend further since there is a non-significant trend suggesting that marine litter may negatively affect ecosystem health using this metric.

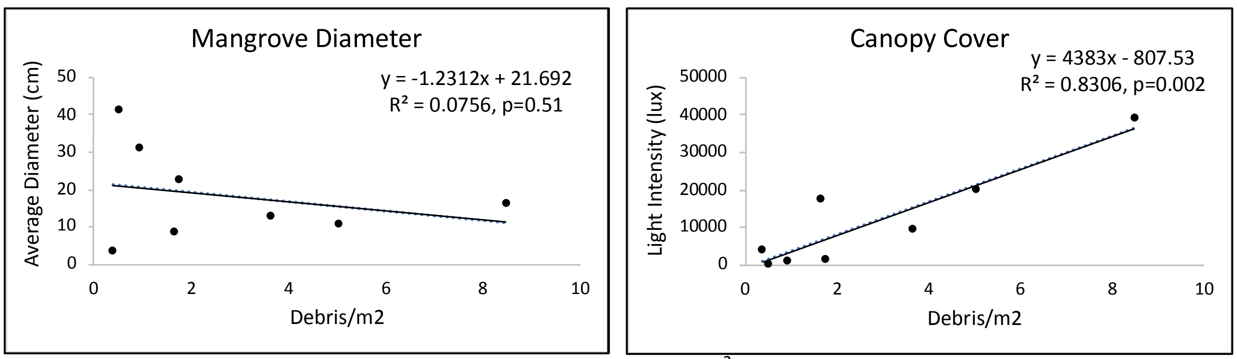

Figure 8. Scatter plots with the total number of debris items per m^2 plotted on the x-axis and the average diameter of mangroves (cm) within each transect (left) and the average light intensity under the canopy of mangroves within each transect (right) on the y-axis. A trendline for a linear regression is shown with the equation, R^2 value and p value denoting significance for each graph.

Summary and Significance of Research & Next Steps

Here, we formed a collaboration between OC, MCD and VASI to conduct a baseline assessment of marine debris in Vietnam. As a case study, we aimed to quantify and characterize the debris in the Red River Delta to begin to understand the amount and characterization of the local contamination, how it is transported, and whether it has an effect on the ecology and conservation of local ecosystems for both wildlife and humans. To meet our objectives, we quantified and characterized debris at five sites in the Red River Delta to better understand the extent of the contamination, compared the quantities and characterization of the debris among sites to better understand sources and transport, and conducted baseline assessments for how the debris may be affecting the health of ecosystems and the resources that they bring to the local community.

(Site 4)

We found marine debris at all 19 locations we surveyed across all five sites. Within a single transect, the amount of debris ranged from 0.14 to 16.9 pieces of debris per m^2. This equates to counting roughly 30 to 3300 pieces of debris in each transect. Similar to other studies around the world, and across all sites here, plastic debris was the dominant material found – making up nearly 87% of all items accounted for. Although the characterization of debris varied among sites, with some sites having more single-use plastics associated with land-based waste and others having more fishing related debris, the five most common items comprised ~68% of all debris accounted for. The top five items found among all locations combined were plastic food wrappers (21% of total), foam fragments (17% of total), plastic bags (16% of total), fabric pieces (8% of total) and pieces of plastic rope and nets (6% of total).

The amount of debris did vary among sites, with the largest amounts of debris found at the transects sampled at the high tide line at site 2 and along the Red River within site 5. In addition, relatively large amounts were found at the one location sampled at site 4 and at one location sampled along the high tide line at site 1. These same locations were also the locations that contained the greatest amount of microplastics – demonstrating that contamination of larger debris in a location contributes to fragmentation and weathering into smaller pieces of microplastics. We considered the characterization of debris among sites as a metric for understanding sources and transport. Our analysis showed that sites 1, 4 and 5 were more similar to each other, and the most different from sites 2 and 3 which were also more similar to each other. For example, the debris in sites 1, 4 and 5 mostly consisted of low-value single-use plastics such as food wrappers and plastic bags. Site 5 also had a relatively high proportion of fabric pieces. These seem to be land-based sources of marine debris that are leaking from communities or industry because they are more difficult or less fruitful to recycle and/or recover. Sites 1 and 5 were in the Red River and Site 4 was on the beach with potential influence from the Red River or the nearby communities. Sites 2 and 3 were dominated by foam fragments, fishing line, and ropes and net pieces. These items are more associated with fishing and aquaculture and are thus appear to be from sea-based sources. Sites 2 and 3 were in the Red River Delta, an area with a lot of fishing and aquaculture activity.

Site 2 (left) and 5 (right)

Finally, we were interested in whether this high abundance of marine debris on beaches and coastlines of the Red River Delta was having any effect on the ecosystem and the well-being of the local community. For all endpoints assessed, we found a trend whereby increased amounts of marine debris led to a decrease in the health of the ecosystem. However, this negative correlation between debris and ecosystem health was only significant for canopy cover – demonstrating a negative relationship between quantity of marine debris and the health of mangroves. As this was only a baseline assessment with relatively few data points, future work should follow up on these trends since the biodiversity and health of the mangrove ecosystem is critical to the health of the local marine ecosystem and to the conservation of marine resources in the Red River Delta. Based on initial conversations with the local community, MCD found that the community members are aware of this issue and agree there is cause for concern – further suggesting future work is needed.

Nam Dinh Community Group Interview

Overall, all parties agree this was a very successful research excursion and are very interested to continue the collaboration to increase the scope and capacity of the research geographically and to answer new questions. Scientific evidence is critical to help us understand the issue and to inform effective positive change. Thus far, our work demonstrates a need for future research and a need to consider how the scientific evidence regarding contamination, sources and effects can inform mitigation strategies. There is no doubt that there is high contamination of marine debris in the Red River Estuary and evidence to suggest this debris may be causing an effect on the health of the ecosystem and the well-being of the local people. The results from this study suggest that some relevant mitigation strategies related to low-value single-use plastics (e.g., plastic food wrappers and bags) and fishing related debris could be immediately useful to prevent marine debris. This may include policies that increase the value of single-use bags and food wrappers, reduce the production and use of hard-to-recycle plastics, or incentivizing fishers to return or at least reduce the leakage of fishing gear to the environment. It may also include strategies aimed at trapping anthropogenic debris in the river and recovering it for management before it makes its way into the Red River Delta.

Finally, this baseline assessment will produce several products and deliverables. As an immediate action, we wrote up this report and summary that can be used to share via multiple means of media with diverse stakeholders (i.e., local governments, organizations, industry and community-members). To assure this work is shared with a broad audience, we will follow this report up with a blog for the Ocean Conservancy and MCD websites that will be translated in English and Vietnamese, a second community consultation in Xuan Thuy National Park to share our findings, snapshots of our work via social media, and a paper about this work to be published in an international peer-reviewed journal. As mentioned above, this work is just the beginning of a collaboration formed to build capacity, increase our understanding, raise awareness and drive positive change towards a reduction of marine debris nationally in Vietnam.

References

Biological Assessment (2018). Background to monitoring mangrove forest health. *Environmental Protection (Water) Policy 2009 – Monitoring and Sampling Manual.* Queensland Government.

Gul, M. R., Griffen, B.D. (2018) Impacts of human disturbance on ghost crab burrow morphology and distribution on sandy shores. *PLoS ONE*. 13, e0209977.

Haneji, C., Amemiya, T., Itoh, K., Mochida, Y., Hoang, T.T.N., Pham, V.C. (2014) Analysis of environmental stressors on ecosystems of Xuan Thuy National Park, Vietnam. *Journal of Vietnamese Environment.* 5, 12-21.

Jambeck, J., Geyer, R., Wilcox, R., Siegler, T., Perryman, M., Andrady, A., Narayan, R., Law, K.L. (2015) Plastic waste inputs from land into the ocean. *Science*. 347, 768-771.

Lahens, L., Strady, E., Kieu-Le, T., Dris, R., Boukerma, K., Rinnert, E., Gasperi, J., Tassin, B. (2018) Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. *Environmental Pollution.* 236, 661-671.

Lam, N.T.H. (2016) Local knowledge amongst farming communities on response to water induces hazards: case study in Xuan Thuy National Park. *International Conference on the Mekong, Salween and Red Rivers: sharing knowledge and perspectives across borders.*

Opfer, S., Arthur, C., Lippiatt, S. (2012). NOAA Marine Debris Shoreline Survey Field Guide. NOAA Marine Debris Program. www.MarineDebris.noaa.gov.

Thanh, T.D. (2003). Researches in the estuarine environment and ecosystem of the Red River: an overview on activities and result. *Collection of works on Marine Environment and Resources.* X, 34-53.

Thanh, H.T., Yabar, H. (2015) Climate change challenges for sustainable coastal wetland management in Xuan Thuy Ramsar Site, Vietnam. *British Journal of Environment and Climate Change.* 5(3), 214-230.

Appendix: Sampling Protocol

Red River Baseline Sampling Effort for Plastic Pollution
A collaboration between MCD, University of Toronto and Ocean Conservancy
Draft 6

NOTE: This protocol is adapted from the 2012 NOAA Marine Debris Shoreline Survey Field Guide. It has been updated since the first baseline assessment, carried out from May 28-31st, 2019.

CONTENTS

BACKGROUND

The Red River Delta is a biodiversity hotspot in the western coastal zone of the Tonkin Gulf, supporting mangrove forests, intertidal habitats, and a key feeding ground for a number of bird species that stop on route during spring and autumn migrations. Out of the seven coastal wetlands in the Red River Delta, Xuan Thuy National Park, located on the right bank side of the estuary in Nam Dinh province of Vietnam, is considered one of the most important ecological sites. Xuan Thuy National Park was recognized for the fundamental ecological functions performed by its wetlands when it was declared the first Vietnamese Ramsar Site in 1982. Xuan Thuy National Park alone has over 14 different mangrove species in its forests, providing an abundant source of food and shelter for over 30 marine species and an important habitat for migratory birds, with 78 species of water birds and 38 species of shorebirds recorded. In addition to being a habitat for rare species of otter, porpoise, and whale, the area has also recorded 111 aquatic plant species, and over 500 species of benthos and zooplankton, including shrimp, fish, crab, and oysters. Not only does the Xuan Thuy site serve as a rich habitat for many threatened species, it also provides natural resources and economic prospects for the livelihood of local human communities.

Due to its importance as a site of socioeconomic development in Vietnam, as well as an increasing human population and therefore growing use of its highly valuable resources, there have been many reports and studies done on various issues within the Red River estuary to address these challenges. These studies were funded and supported by a range of academic institutions and international organizations, including the Hai Phong Institute of Oceanography, the Institute for Ecology and Biological Resources, Hanoi (IEBR), the World Conservation Union (IUCN), the Mangrove Ecosystem Research Centre (MERC), and the Ministry of Agriculture and Rural Development (MARD) among others. However, according to Tran Duc Thanh's review of the literature in 2003, there are still major gaps in the research that make it difficult to track ongoing changes to the ecosystem and the causes behind those changes. In recent years, more studies have been done to assess the impact of climate change particularly on the Xuan Thuy Ramsar site. Thanh and Yabar (2015) described the vulnerability of Vietnam's coastal wetlands and presented an overview of the main challenges for the sustainable management of the Xuan Thuy Ramsar site. Their research in addition to others shows that there needs to be the development of a long-term conservation plan. Other research related to Xuan Thuy site look into more specific areas, such as one that analyzes environmental stressors on Xuan Thuy's mangroves (Haneji, Amemiya, Mochida, Hoang, & Pham 2014) and another that discusses the importance of local community knowledge and reactions to natural hazards (Nguyen Thi Hong Lam, 2016. Previous literature thus far suggests multiple areas of research opportunities that would greatly contribute to the ongoing conversation about the Red River estuary and its conservation, and would further inform national and local stakeholders about the best strategies to improve sustainable measures for this area.

OBJECTIVES

1. Conduct a baseline study of anthropogenic debris in the Red River Delta (near mouth of river, and within estuary), including within the mangrove forest.
    c. Quantify and characterize anthropogenic debris (e.g., plastic, metal, glass) along the shorelines and tidal flats of the estuary and mangrove forest, and upstream of the delta in and along the Red River.
    d. Quantify and characterize microplastics along the shorelines and tidal flats of the estuary, and upstream of the delta in and along the Red River.
2. Compare the types and distribution of anthropogenic debris from the river to the ocean across the landscape to help us understand sources and fate.
    a. Assess patterns for where anthropogenic debris resides across the landscape (e.g., entrained in roots, floating vs. sinking, degradation patterns)
    b. Compare anthropogenic debris distribution between shoreline, tidal flat, and upstream data to help determine sources of waste.
3. Assess how anthropogenic debris affects mangroves and the biodiversity within the mangrove ecosystem, ultimately affecting local people and the planet.

BEFORE YOU BEGIN

Before any data collection begins, the area should be surveyed to determine which areas will be surveyed. Sites should be assessed for safety, accessibility, and consistency between other sites (mangroves are present, crab holes present). Once the general area has been surveyed, a list of sites and site IDs can be created. See Appendix for list of the site locations and IDs used on May 28 – 31, 2019. On this data sheet you will note:

Safety is a priority. Do not touch or lift potentially hazardous or large, heavy items. Notify your local officials if such items are encountered.

For the surveys, you will need the following materials and supplies:

- Data sheets printed on waterproof paper (Per transect - 3 Debris Density sheets; 1 Biodiversity [Quadrat] sheet, 1 Biodiversity [Mangrove] sheet, 1 Microplastic sheet)
- Waterproof paper (extra)
- Small measuring tape
- Pencils/pens (10 of each)
- Labeling tape
- Purell
- First Aid Kit
- Clipboards (3 + 1 extra)
- Sunscreen
- Bug spray
- Permanent markers (10)
- Duct Tape
- Flags (10 minimum)

- PP plastic 8oz jars (1 per transect + 1 field blank per day + extras) - wash with detergent and RO, rinsed with RO three times, capp and pack
- Squirt bottle (1 + extra)
- Metal spoon (1 + extra)
- 2mm sieve
- Mini transect (2)
- App for light measurements – Light Meter Pro
- Quadrat 1x1 m (2)
- Transect tape (2)
- GPS
- extra batteries for the GPS
- Light Meter App on Smartphone
- Camera
- Work gloves
- Mud socks/shoes
- Headlamps
- Cooler or bag for microplastics samples
- Bag to hold field equipment

PROTOCOL

To address **objective 1a**, we will conduct standing stock surveys along the shoreline and within the mangrove forest in, 50-meter long transects. Transect size can be reduced if density of debris is high, as long as the size of the transect is recorded. Sites are located within and nearby Xuan Thuy National Park along the Red River (Site 5), at the river mouth (Site 1), within the protected delta (and near intensive aquaculture; Site 3) and facing the ocean (Sites 2 and 4; see map in Figure 1). To address **objective 1b,** sediments will be collected in each surveyed transect and analyzed for microplastics (in the field). To address **objective 2a,** we will conduct standing stock surveys in 50-m long transects, spaced 5-7 meters apart, moving from the high tide line of the estuary out towards the water (See map in Figure 1, red bars). To address **objective 2b,** we will compare the signatures of debris from the standing stock surveys among our sites. To address **objective 3,** we will quantify crab burrow density, mangrove diameter, and canopy cover in three quadrats within each transect that has mangroves and crab holes (See Figure 2). See Table below for a list of which sampling locations will be sampled for which metrics.

Colour	Dimensions (long = length of shoreline, wide = perpendicular to shoreline)	Description	Location	Sampling
yellow	50-m long x 5 m wide	transect	- incorporate the high tide line	- standing stock survey of anthropogenic debris - microplastics - mangrove diameter and canopy cover -crab holes
red	50-m long x 5 m wide	transect	-starting at high tide line, moving out towards the open ocean and mangroves	- standing stock survey of anthropogenic debris - microplastics - crab holes
blue	50-m long x 5 m wide	transect	-shoreline of river	- standing stock survey of anthropogenic debris - microplastics

Standing Stock Surveys of yellow, red, and blue transects

1. Sketch your 50-m x 5m shoreline site. Using your transect tape, begin at the start of your shoreline section and mark the four selected transect boundaries with flags. Record GPS coordinates for each corner of the transect in decimal degree format (Figure 2).
2. If sampling for biodiversity and microplastics (Map, yellow and red), the team will split into three groups, each with a different job. One person will complete the Biodiversity (Quadrat) Assessment Sheet (see step 3), one will complete the Microplastics Sampling Sheet (see step 4), and one will complete the Biodiversity (Mangroves) Assessment Sheet (see step 5; Appendix XX). If not sampling for microplastics and biodiversity, skip to step 6.
3. **Biodiversity (Quadrat) Assessment:** Randomly drop a 1 x 1 m quadrat three times in the transect. The quadrats should be randomly placed between 0 – 15 m, 15 – 30 m, and 30 – 50m, and will be sampled for crab burrow density.
    a. Record the GPS coordinate of the center of the quadrat.
    b. Take a photograph of the datasheet noting the transect ID. Then take one photograph of the quadrat.
    c. ***Sample crab burrow density:*** count the number of crab burrows in the quadrat. Count a burrow if it is larger than your pinky finger (approximately 1 cm diameter), and if any part of it is included in the quadrat. Consult a team lead if you are unsure if something is a crab burrow (Figure 3). Throw down transects before people walk all over transect so boots don't alter the landscape.
    d. Repeat steps 3a) – 3c). You should have photos and data for 3 quadrats.
4. **Microplastics Sampling Sheet:** Microplastics will be sampled in the center of the transect (25 m). Drop a 10 cm x 10 cm mini quadrat at the 25 m mark; Collect samples always in the high tide line when relevant (Figure 2).
    a. Take a photograph of the datasheet noting the transect ID. Then take one photograph of the mini quadrat.
    b. Using a clean spoon, collect all the surface sediment from the inside of the of the mini quadrat within a 10cm x 10cm transect, and place into a clean, labelled 8oz PP/glass jar (Note collector name, date, site ID, and sample type – MP).
    c. Give the sample to your site lead for storage.
    d. Circle "YES" on the Microplastics Sampling Sheet to note that the microplastics sample was collected. Note whether or not the sample is in the high tide line.
    e. Once microplastics sampling is complete, take photographs of the entire transect.
        1. Take a photograph of the datasheet noting the transect ID
        2. Take photographs of the entire transect.
5. **Biodiversity (Mangrove) Assessment Sheet:** Walking along the long edge of the transect, measure mangrove diameter and canopy cover on a randomly selected tree every 5 m.

a. ***Sample mangrove diameter:*** starting at one side of the long end of the transect, randomly select a mangrove tree.
b. If mangrove has a single trunk, measure the diameter of the tree right before the main trunk branches. If the mangrove is bush-like, select the largest trunk, and measure the diameter right before the main trunk branches (Figure 4).
c. ***Sample for canopy cover:*** using a light meter, record the light intensity outside of the mangroves. Record in "LIGHT INTENSITY OPEN AIR (LUX) " field. Then, place the light meter under the canopy and record light density in "LIGHT INTENSITY UNDER MANGROVE (LUX)" field.
d. Walk 5 m along the transect and repeat steps 5. a) – c). . You should have 10 diameter measurements, and 10 paired (under canopy, open air) light intensity measurements for each of your transects. If no mangrove there, just put NA.

6. **Debris Survey:** Begin filling out your Debris Density Data Sheet. The transect will be split into three sections. Each team member will survey one section of the transect on their own data sheet (0-15m, 15-30m, 30-50m). Flags can be put down along the transect to help with this.

e. Walking in an "S" shape ocean side to the mangrove side, record on your Debris Density Data Sheet counts of debris items that measure over 2.5 cm in the **longest** dimension. Record the material type in accordance with the datasheet. *Remember that for standing-stock surveys, debris is not removed from the shoreline.* Record large debris items, anything bigger than 1 foot (~ 0.3 m, typical forearm length from palm to elbow) in the large debris section of the Debris Density Data Sheet.
f. NOTE: you may add any items that are not included on the datasheet to your datasheet. Make sure to discuss with other team members before doing so to standardize how you are classifying items.

6. Take photos of some of the debris items!

RESEARCH QUESTIONS

Objective 1
Within all of a 50m x 5m transects, anthropogenic debris items will be counted, and characterized. With the yellow transects, we hope to answer the following questions: (1) Does the distribution of debris vary depending on the location along the shoreline? (2) Are some areas of the shoreline more dense with debris than others? Certain kinds of debris? (3) What microplastics are found in the surficial sediment of the estuary and mangroves?

Objective 2
Within all of a 50m x 5m transects, anthropogenic debris items will be counted, and characterized. With the yellow, red, and blue transects, we hope to answer the following questions: (1) Within one location along the shore, does the type, or size of litter vary as you get closer to the shore/ocean? (2) What are the patterns of waste distribution across the landscape (e.g., entrained in roots in mangroves, floating vs. sinking, degradation patterns, how

does the debris in the mangroves compare to the debris on the tidal flats)? (3) Are there discernable differences in the waste coming from the ocean compared to from the red river?

Objective 3

Within the quadrats of some transects we hope to answer: (1) How is mangrove biodiversity (species present, mangrove growth/health, crab burrow density) affected by plastic pollution/ waste? (2) Are there differences in the response of different species (i.e. mangroves versus crabs) to anthropogenic debris?

ANTICIPATED RESULTS

Objective 1

Data summary: Quantity of plastic or other anthropogenic debris items/50m x 5 m transect.

Characterization of debris by type and size per transect

Quantify and characterization of microplastics (> 2 mm) per transect

Objectve 2

Amount and composition of debris may vary as you move closer to the ocean and farther from the river in both as you move out to sea and west of river mouth.

Objective 3

Data summary: Three measures of biodiversity health: crab burrows/ m^2, average canopy cover, average mangrove diameter.

APPENDIX A

LEGEND

	location	sampled for
red line	tidal ats	anthropogenic debris, microplastics, biodiversity (TBD)
yellow line	shoreline	anthropogenic debris, microplastics, biodiversity
blue line	boom	anthropogenic debris, microplastics

Figure 1: Site overview. Yellow lines demarcate where transects will be surveyed for (1) anthropogenic debris, (2) microplastics, and (3) biodiversity along the shoreline within the mangroves. Red lines demarcate where transects will be surveyed for (1) anthropogenic debris, (2) microplastics, and (3) biodiversity, along the tidal flats. Blue lines demarcates where transects will be surveyed for (1) anthropogenic debris, (2) microplastics, and (3) biodiversity if within the mangroves.

Table 1: list of site locations and ID names

Site ID	Latitude	Longitude	Colour on map	

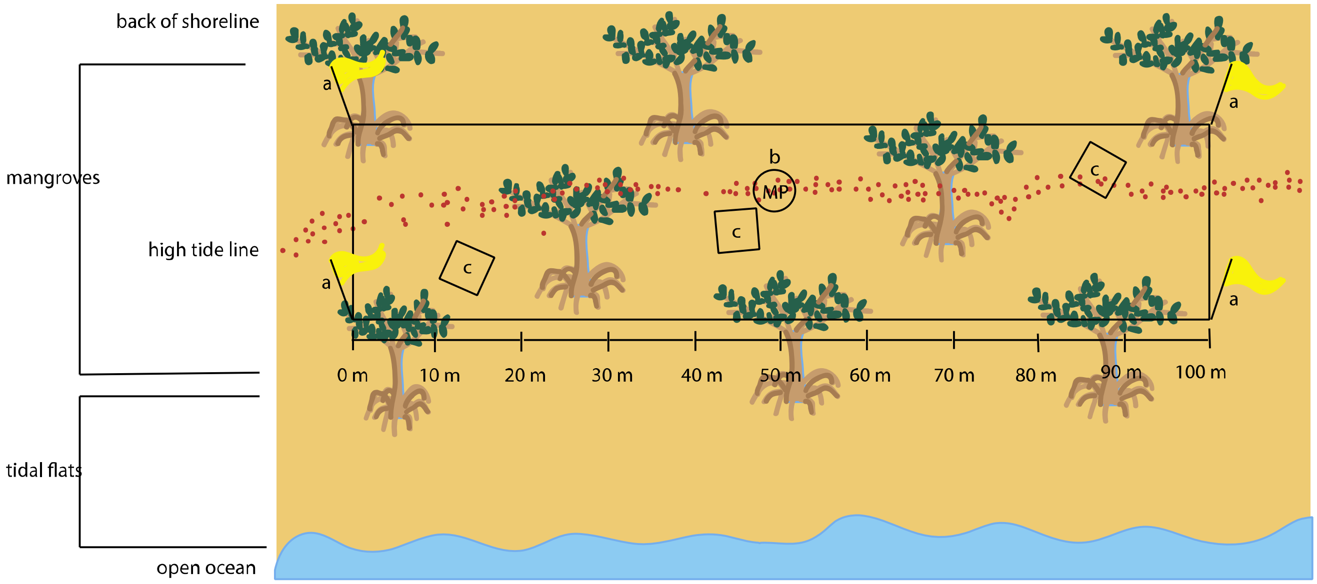

Figure 2: map of a transect. Four flags (a) will demarcate the boundaries of each transect. Microplastics will be collected from the center (50 m) of the transect (b); where relevant, microplastics will be collected from the high tide line as demonstrated here. Three quadrats will be randomly placed between 0 – 33 m, 33 – 66 m, and 66 – 100 m (c) and sampled for crab burrow density, and dead vs. live stems. Starting at 0 m, the diameter-at-breast-height (DBH) of one mangrove will be measured every ten meters, for a total of ten mangroves measured per transect.

APPENDIX B: DATA FORMS

NOAA Marine Debris Shoreline Survey Field Guide | 2012

SHORELINE DEBRIS **Debris Density Data Sheet**	Organization		Name of organization responsible for data collection
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
Complete this form during **EACH** survey or transect (if standing-stock) per site visit	Email address		Email contact for surveyor
	Date		Date of this survey

ADDITIONAL INFORMATION

Shoreline name			Name for section of shoreline (e.g., beach name, park)
Survey Type	Accumulation ☐	Standing-stock ☐	Type of shoreline survey conducted (check box)
Transect ID # (N/A if accumulation survey)			Transect ID (include shoreline ID, date, and transect #)
Coordinates of start of shoreline site	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees). Record in both corners if width > 6 m. If transect, record at water's edge.
Coordinates of end of shoreline site	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees). Record in both corners if width > 6 m. If transect, record at back of shoreline.
Width of beach			Width of beach at time of survey from water's edge to back of shoreline (meters)
Time start/end	Start	End	Time at the beginning and end of the survey
Season			Spring, summer, fall, winter, tropical wet, etc.
Date of last survey			Date on which the last survey was conducted
Storm activity			Describe significant storm activity within the previous week (date(s), high winds, etc.)
Current weather			Describe weather on sampling day, including wind speed and % cloud coverage
Number of persons			Number of persons conducting the survey
Large items	YES	NO	Did you note large items in the large debris section?
Photo ID #s			The digital identification number(s) of debris photos taken during this survey.

Notes: Evidence of cleanup, sampling issues, etc.

DEBRIS DATA: (continued on back)

ITEM	TALLY (e.g., 𝍸)			TOTAL
PLASTIC				
Plastic fragments	Hard	Foamed	Film	
Food wrappers				
Beverage bottles				
Other jugs or containers				
Bottle or container caps				
Cigar tips				
Cigarettes				
Disposable cigarette lighters				
6-pack rings				
Bags				
Plastic rope/small net pieces				
Buoys & floats				
Fishing lures & line				
Cups (including polystyrene/foamed plastic)				
Plastic utensils				
Straws				
Balloons				
Personal care products				
Other:				
METAL				
Aluminum/tin cans				
Aerosol cans				
Metal fragments				
Other:				
GLASS				
Beverage bottles				
Jars				
Glass fragments				
Other:				

ITEM	TALLY (e.g., 卌)	TOTAL
	RUBBER	
Flip-flops		
Gloves		
Tires		
Rubber fragments		
Other:		
	PROCESSED LUMBER	
Cardboard cartons		
Paper and cardboard		
Paper bags		
Lumber/building material		
Other:		
	CLOTH/FABRIC	
Clothing & shoes		
Gloves (non-rubber)		
Towels/rags		
Rope/net pieces (non-nylon)		
Fabric pieces		
Other:		
	OTHER/UNCLASSIFIABLE	

***LARGE DEBRIS ITEMS* (> 1 foot or ~ 0.3 m)**

Item type (vessel, net, etc.)	Status (sunken, stranded, buried)	Approximate width (m)	Approximate length (m)	Description / photo ID #

Notes on debris items, description of "Other/unclassifiable" items, etc:

MICROPLASTICS SAMPLING SHEET

SITE INFORMATION

complete this form once for each transect	
DATE (DD- MM - YYYY)	
SHORELINE NAME	
TRANSECT ID	
START TIME	
END TIME	

	FIRST NAME	LAST NAME	AFFILIATION	PHONE NUMBER
MICROPLASTICS SAMPLER				
BIODIVERSITY SURVEYOR				
MAGROVE SURVEYOR				

MICROPLASTICS SAMPLING

MP SAMPLED?	YES	NO
MP IN HIGH TIDE LINE?	YES	NO

PHOTO OF TRANSECTS TAKEN WITH PHOTO OF DATASHEET	YES	NO

MICROPLASTICS SAMPLING SHEET

SITE INFORMATION

complete this form once for each transect	
DATE (DD- MM - YYYY)	
SHORELINE NAME	
TRANSECT ID	
START TIME	
END TIME	

	FIRST NAME	LAST NAME	AFFILIATION	PHONE NUMBER
MICROPLASTICS SAMPLER				
BIODIVERSITY SURVEYOR				
MAGROVE SURVEYOR				

MICROPLASTICS SAMPLING

MP SAMPLED?	YES	NO
MP IN HIGH TIDE LINE?	YES	NO

PHOTO OF TRANSECTS TAKEN WITH PHOTO OF DATASHEET	YES	NO

BIODIVERSITY (MANGROVE) ASSESSMENT SHEET

SITE INFORMATION

complete this form once for each transect	
DATE (DD- MM - YYYY)	
SHORELINE NAME	
TRANSECT ID	
START TIME	
END TIME	

	FIRST NAME	LAST NAME	AFFILIATION	PHONE NUMBER
MICROPLASTICS SAMPLER				
BIODIVERSITY SURVEYOR				
MAGROVE SURVEYOR				

MANGROVE ASSESSMENT

	0 m	5 m	10 m	15 m	20 m	30 m	35 m	40 m	45 m	50 m
DIAMETER AT BREAST HEIGHT (CM)										
LIGHT INTENSITY OPEN AIR (LUX)										
LIGHT INTENSITY UNDER MANGROVE (LUX)										

NOTES

BIODIVERSITY (QUADRAT) ASSESSMENT SHEET

SITE INFORMATION

complete this form once for each transect	
DATE (DD- MM - YYYY)	
SHORELINE NAME	
TRANSECT ID	
START TIME	
END TIME	

	FIRST NAME	LAST NAME	AFFILIATION	PHONE NUMBER
MICROPLASTICS SAMPLER				
BIODIVERSITY SURVEYOR				
MAGROVE SURVEYOR				

QUADRAT ASSESSMENT

COORDINATES	LATITUDE	LONGITUDE	PHOTO TAKEN?
QUADRAT 1			YES / NO
QUADRAT 2			YES / NO
QUADRAT 3			YES / NO

	QUADRAT 1	QUADRAT 2	QUADRAT 3	DESCRIPTION
CRAB BURROW DENSITY				# OF CRAB BURROWS IN QUADRAT

NOTES

APPENDIX C: RESOURCES FOR BIODIVERSITY SURVEY

Figure 1: some crab holes within a quadrat are highlighted in yellow. Only crab holes larger than the surveyor's pinky finger (approx. 1 cm diameter) were counted.

Figure : Measurement location (in yellow) for branching mangrove (left) versus single trunk mangrove (right)